BBC RD 1996/13

Research and Development Report

PLANTX:

The universal tool for digital and analogue transmitter planning

M.P. Shovelton, M.Eng.(Hons), A.C.G.I.

Research and Development
Policy and Planning
THE BRITISH BROADCASTING CORPORATION

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Summary

Terrestrial radio-frequency planning is undergoing a revolution. With the movement of broadcasters towards digital transmission, the RF planning book is being re-written. The design of digital transmitter networks demands new techniques and innovative new prediction tools in order to allow these networks to be accommodated within the already tightly-packed broadcast spectrum (that is, be interleaved with existing analogue channels).

Over the past three years, BBC Research and Development, Spectrum Planning Group, has put considerable effort into the research and development of a prediction tool that will allow efficient planning of both digital and analogue transmitter networks for television and radio services. This Report records the results of this work, by describing in basic detail, the prime facilities that are provided for planning transmitters by the newly-developed software prediction tool that now bears the name 'PlanTx'.

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1. INTRODUCTION

This Report is concerned with a new system for overcoming most of the principal problems involved in predicting the overall performance of broadcast RF channels. Powerful desktop personal computers have enabled BBC R&D's Spectrum Planning Group to develop the software suite 'PlanTx' as a universal tool for digital and analogue transmitter planning. Terrestrial radio-frequency planning is currently undergoing a revolution and the new BBC 'PlanTx' system is an essential and flexible tool designed to assist in this process.

The BBC has, for more than 60 years, carried out measurements and test procedures to provide for the satisfactory reception of its broadcasting output. In the early days of broadcasting, the BBC had conservative expectations. An uncrowded spectrum and limited requirements for 'filler' stations resulted in a more empirical way of setting up new services.

Initially, much of the spectrum planning work was done by engineers studying documented information, and then calculating the possible sites, polarisations, ERPs, and antenna radiation patterns for each service area. Theoretical work, as well as previously recorded practical results, enabled this activity to be successful.

Early desktop computers made regular use of BBC-developed software programs, as well as adapted imported commercial packages.

Today the demands being made by the broadcasting industry for more terrestrially-transmitted services, using advanced technologies, has placed considerable strains on spectrum planning engineers to find usable RF channels to satisfy these demands.

The BBC introduced Digital Audio Broadcasting (DAB) in the UK, as a pilot service in September 1995 and a trial digital terrestrial television service* (DTT), with three programme channels and one facilities service, commenced during April 1996. These transmissions are being made for the benefit of receiver manufacturers, as well as broadcasters.

The terrestrial analogue PAL-television system in the UK is now available on four separate programme channels to over 99% of the UK population and a fifth programme channel to about 60% (exclusively in the UHF band). To achieve this, over 1000 transmitter sites have to be used, requiring 4,000 transmissions for the four programme-channel coverage. Within the UHF Bands IV and V, there are only 48 channels with just 46 currently available for use (early 1997), each having 8 MHz bandwidth. Consequently, the available channel frequencies must be used repeatedly (over 100 times) to achieve the >99% nationwide coverage.

The proposed new terrestrial digital channels must therefore use whatever spare capacity the present allocations of frequencies will allow; interleaving of the digital transmissions where necessary. To prevent digital transmissions interfering with current analogue channels, or analogue channels causing interference to digital channels, it can be seen that stringent demands are being placed on the spectrum planning of a new digital service.

The prediction of suitable frequencies or channels for these new services is a huge task bearing in mind that receiver sensitivities, receiver local oscillator radiation, image channels, upper and lower adjacent channel interference (receiver selectivities) and differences of cross-polar and angular discrimination of antennas, all need to be accounted for. Added to this, are the possibilities of severe interference occurring during periods of anomolous propagation, and the full allowances that must be made for potential interference to and from other countries.

2. INITIAL REQUIREMENTS

2.1 Basic principles

Over the past four years, BBC R&D Spectrum Planning Group has put considerable effort into producing a pre-

Fig. 1 - Photo of a BBC Spectrum Planning team at work.

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* This work, and the overall network planning, is being carried out jointly with the Independent Television Commission and National Telecommunications Limited.

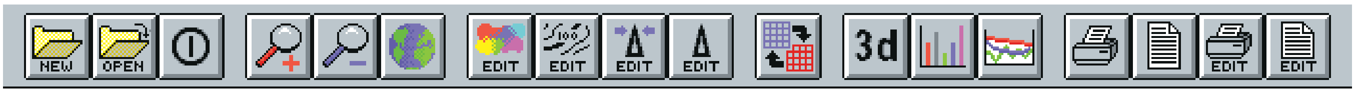

Fig. 2 - The 'PlanTx' PC Toolbar for Incoming Interference Analysis use.
(The PC Windows toolbar feature will be a familiar sight to any PC user.
The specialist icons are dealt with in later Sections of this Report.)

diction tool that would allow efficient planning of both digital and analogue transmitter networks for radio and television. The result of this work has been to produce a system that now bears the name 'PlanTx'.

At the start of the project, the available planning tools consisted of basic textual, batch-processing systems. Little was then known about what a fully-interactive, graphical system would be capable of delivering; so the initially-defined requirements for PlanTx were kept deliberately vague. The development cycle was an iterative, exploratory one, where different types of prediction, analysis and display were tested; but at the same time, allowed constant feedback from the early users. This method of approach resulted in the development of a very powerful tool with a far greater functionality than would have been obtained if rigidly-defined requirements had been laid down.

Nevertheless, some initial *guidance*, even if vague, as to what features might be incorporated into the system, needed to be sketched out so that essential features should not be overlooked. A listing of these basics was then produced, with the following requirements:

- it should be a terrestrial radio-frequency prediction tool capable of dealing with analogue and digital transmission prediction;
- it should not be limited by either geographical location or transmission type;
- it should be able to deal with incoming and outgoing interference scenarios;
- a variety of prediction algorithms should be available;
- there should be powerful tools for real-time analysis of field strength predictions; including the ability to modify most transmitter parameters for display in 'near real-time';
- it should be capable of displaying prediction results in various forms;
- there should also be the ability to analyse heterogeneous transmission interference scenarios; i.e. the effect of a transmission of one type interfering with reception of a transmission of a different type.

In the event, these requirements became embedded parts of the design, as will become clear when reading later Sections of this Report. The following Subsection therefore gives an indication as to how some of these features were fitted into the initial stages of the project.

2.2 Design philosophy

The development of PlanTx was founded on the need for four basic principles to be met:

2.2.1 Flexibility

A quality that was to ensure that the system should not be limited by either geographical location or type of transmission. The ultimate transmitter planning tool would allow modification of any transmitter parameter in *real time*. Unfortunately, due to the complexity of terrain-based prediction methods, this is not possible at present; but it is anticipated that with the inevitable increase in computational power, this innovation will be possible in the future.

2.2.2 Usability

This was an obvious need if the system was to be a worthwhile tool. It needed to be intuitive to use, and for this purpose Microsoft Windows* was chosen to be the user-interface, as most prospective users would likely be familiar with the PC and this particular front-end. Most importantly, having a portable (notebook) PC, enables ease of use away from base; while each user's needs would also be met by a cost-effective desk PC back at base (a ubiquitous feature nowadays).

2.2.3 Power for analysing

To achieve maximum power of analysis, it is necessary to allow as many calculation parameters as possible to be modified at the analysis stage. PlanTx attempts to commit as few parameters as possible at the *early stage*, thus allowing a more powerful and flexible analysis to be carried out. For example, the only transmitter parameters that are *fixed* are those relating to the physical antenna location — all other parameters are *modifiable* during the analysis stage. The fixed parameters do not generally cause a problem, because there is often a very limited choice of transmitter site. Fig. 2 shows the PC Toolbar used when editing calculations and transmitter parameters etc. for the 'Incoming Interference Analysis' mode (see Section 6).

2.2.4 Future-proofing

Considerable care has been taken to ensure that PlanTx is future-proofed, with four main areas of un-

* Registered Trade Mark of Microsoft Corporation Inc.

certainty being identified:

- the format and structure of terrain height data;
- the format of geographical location specifiers (map grid references);
- the types and characteristics of terrestrial transmission systems;
- the field strength prediction algorithms.

It would clearly be impossible to predict how each of these areas is going to develop in the future. Indeed, in the case of terrain data, it would be impossible to cater for all the formats that exist at *present*.

In order to counter this uncertainty, a dynamically-linking library structure was developed. Consequently, a library now exists for each grid system and each transmission system (see Section 4). Each library* provides a common set of functions, so that PlanTx can treat each library in the same manner, regardless of its content. This means that when new systems are developed at a later date, they can then be directly attached to the system by simply writing a new library.

3. THE 3-STAGE PLANNING PROCESS AND CHOICE OF COMPUTER TYPE

Terrain path-based prediction methods, such as the method used by the BBC**, are extremely complicated and require a great deal of computer processing. This makes real time analysis of large predictions impossible. PlanTx uses a compromise, using a three-stage planning process (with **specification**, **analysis** and **calculation** stages). Each stage has its own specific hardware and operating system requirements. The stages are divided between two pieces of hardware: a PC (running Windows), and a Sun SPARC system (running UNIX). The former is used for the specification and analysis stages, where a high degree of user interaction is needed, and the latter provides considerable processing power and multi-tasking capability.

Other advantages of this arrangement include cost effectiveness, in that each user need only possess a PC; plus, the ability to take calculated results files off site, to be analysed on a portable PC. High-end PCs are also generally cheaper than UNIX colour X-Terminals (required for a system based entirely on X Windows and UNIX).

3.1 Specification and analysis

As these stages involve a high degree of user interaction, the design-and-feel of the user interface is very important. For this reason, it becomes clearer why an IBM-compatible PC computer, running the Windows graphical user interface (GUI), was chosen — most users do have a high degree of familiarity with this particular GUI. The analysis stage requires a lot of processing power, and for this reason, a high-end 486 (or later) PC is used.

3.2 Calculation

The calculation stage basically requires a great deal of raw processing power. It also requires multitasking (to allow more than one calculation run to be performed simultaneously). A Sun SPARCstation running UNIX is therefore used for this stage.

The calculation-computing on the SPARCstation is directly controlled by the PC-based GUI (Windows) via a WinSock-compliant network. Fig. 3 illustrates the software arrangement and the communication between the modules.

4. GRID SYSTEMS USED WITH TERRAIN INFORMATION

A particularly important requirement for the prediction system was that it should be able to predict field strengths anywhere in the world. But there are two main hurdles to overcome in achieving this goal:

- **Firstly**, a wide variety of geographical co-ordinate systems are used thoughout the world. In the United Kingdom, as an example, British National Grid (BNG) references are used; whereas, in Germany, Universal Transverse Mercator (UTM) co-ordinates are used. A simple solution would be to use latitude/longitude pairs for specifying *all*

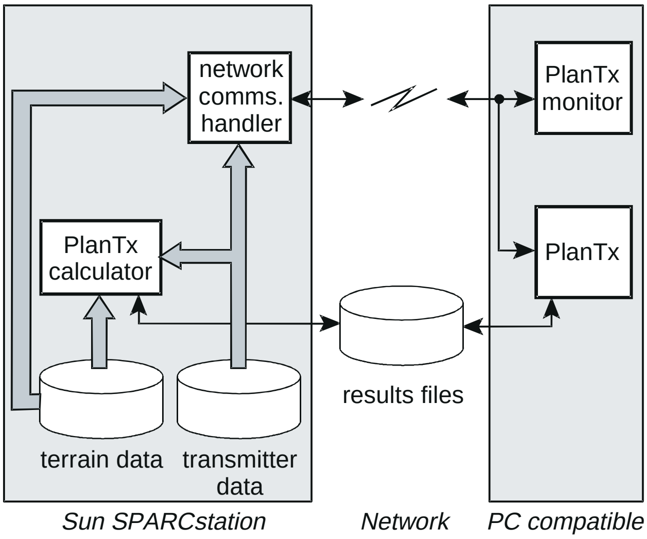

Fig. 3 - The 'PlanTx' software structure and processing.

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* Each 'library' is a section of code capable of dealing with its own variant of the grid system, or transmission system.

** See Appendix.

Table 1: Currently available grid systems.

Ident.	Terrain Database	Coordinate System	Covered Areas
osg	OS 50 m UK	British National Grid	Mainland UK; Orkneys; Shetlands; Scillies; Isle of Wight; Isle of Man
ukg	500 m UK	British National Grid	As for osg plus the Channel Islands; Cherboug Peninsula
irg	500 m Ireland	Irish National Grid	Mainland Ireland (including Eire and Northern Ireland)
cog	5 km Europe	Proprietary coordinate system based on BNG	France; Benelux; Germany; some of Spain, Italy, Switzerland
llg	GLOBE 1 km World	Latitude, Longitude	90% of the world
sng	100 m Singapore	Singapore Grid System	Singapore and nearby small islands

co-ordinates. However, this is not a satisfactory solution, because latitude and longitude readings are unfamiliar to most users and would therefore reduce the usability of the software. Table 1, above, lists the grid systems for PlanTx that have been developed to date.

- **Secondly**, any field-strength prediction algorithm must take the terrain into full consideration; this being an extremely important part of signal strength prediction. But available terrain data for different parts of the world will be structured according the particular co-ordinate systems used in those areas, and will consequently be presented in different data formats. It would be possible, of course, to convert all the *resulting* data to a global format, but this would require additional computation and could introduce inaccuracies into the recalculated data.

To solve the two problems above, PlanTx introduces the concept of *grid systems*. A grid system is an encapsulation of *terrain data* and the *co-ordinate system* used to access it. Internally, the main system program recognises only latitude and longitude; local coordinate systems appear to it to be merely character strings. The task of converting these character strings to latitude/longitude is delegated to the individual grid system libraries. The grid system libraries provide a homogeneous interface to their respective terrain data. This arrangement is illustrated in Fig. 4:

5. TRANSMISSION SYSTEMS

Another essential requirement for any planning tool is that it should be able to deal with any type of transmission *system*. There are several variables:-

- Frequency specification type (whether known as actual frequencies or as channels);
- Frequency band;
- Transmission type (analogue/digital);
- Network type (SFN/MFN)*;
- Modulation system (FM/AM/COFDM);
- Protection ratio requirements for interference calculations;
- Receiving antenna characteristics.

These specifics are enlarged upon in the text that follows; the table opposite, lists the current UK situation.

Different broadcast transmissions use different practices for specifying frequencies. For example, UHF television uses *channel numbers* that are related to frequencies; whereas, VHF radio programmes are identified by using the actual *centre frequency values* themselves.

The *protection ratios*, used for making interference calculations, are different for each combination of wanted and interfering transmission system. Similarly, receiving antenna characteristics, in terms of the

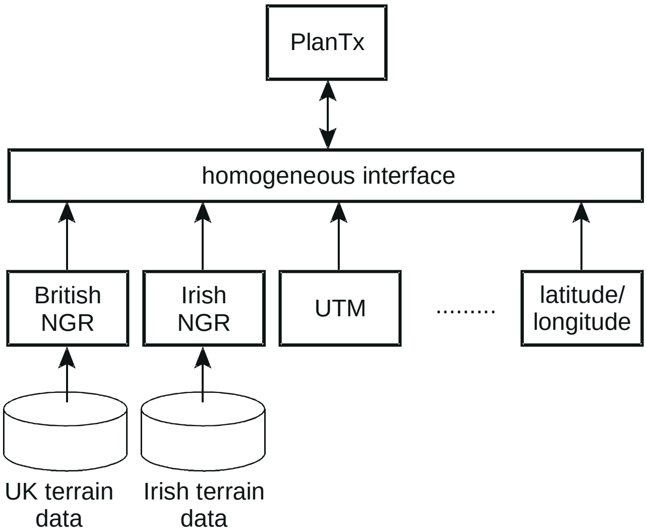

Fig. 4 - The ‘PlanTx’ Grid System structure.

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* Multiple Frequency Network, otherwise known as a conventional or interleaved network.

protection they offer against interfering signals, can also be different for each system.

Other *system-dependent* features include the differences that occur for: adjacent channel interactions; the algorithms used for combining incoming signals; the way results are calculated — for digital systems, it is, for example, most useful to calculate the 'percentage of locations coverage' (that is, the percentage of an area for which a service is received; whereas, analogue systems use 'coverage margin').

A similar solution has been adopted for collating the necessary *related* transmission system elements (homogeneity) as was used for coping with the different national grid systems (Section 5): meaning, each type of transmission system has been supplied with its own dynamically-linked *library* that performs functions that are specific to that system. The homogeneous interface between PlanTx and the libraries allows appropriate connections to be made between the relevant elements, with each library providing the following functions:

- handling frequencies in a format appropriate to the specific transmission system under inspection;
- correcting the assumed 1 kW omni-directional transmitter field strengths, to those of the actual transmitter;
- identifying reference transmitters and calculating protection ratios;
- calculating matrix cell values from the available data using different algorithms (see 'Displayed Matrix Calculations' later in Section 6.2)

The library structure, that has been adapted and operated for homogeneous purposes, can also cope with interactions between *different* (heterogeneous) transmission elements; as between a digital television signal interfering with an analogue television signal, for example. This is an essential feature for dealing with the current efforts to interleave digital television signals with existing analogue ones, in preparation for the intended UK terrestrial digital television network. The two Sections which follow deal with the use of these libraries.

6. INCOMING INTERFERENCE ANALYSIS

This forms the largest part of the PlanTx software, where the coverage of a wanted transmitter(s) is calculated, taking into account terrain and interference effects.

To carry out the analysis, a **matrix system** is used. A matrix is a rectangular area of regularly-spaced *receiver locations* at each of which a group of field strength calculations are made from a list of transmitters; that is, both wanted and interfering transmitters (UK and continental). (It should be accepted that receiving antennas are often deliberately directed to receive programmes that are really designated for viewers and listeners in other areas. Sometimes this is done because the local terrain causes an unacceptable depletion in the level of the designated signal — note, though, that the analysis program assumes that receiving antennas are actually directed towards the *designated* transmitter. This is one important factor that makes the interleaving of new services more complex.) The calculations will give numerous combinations of results, ranging from a basic individual local transmitter signal strength, to the expected interference levels from transmitters located outside the service area being inspected (see Section 6.2).

6.1 Basic procedure

There is a basic three-stage procedure for performing an incoming interference analysis: this consists of **specification**, **calculation** and **analysis** processes.

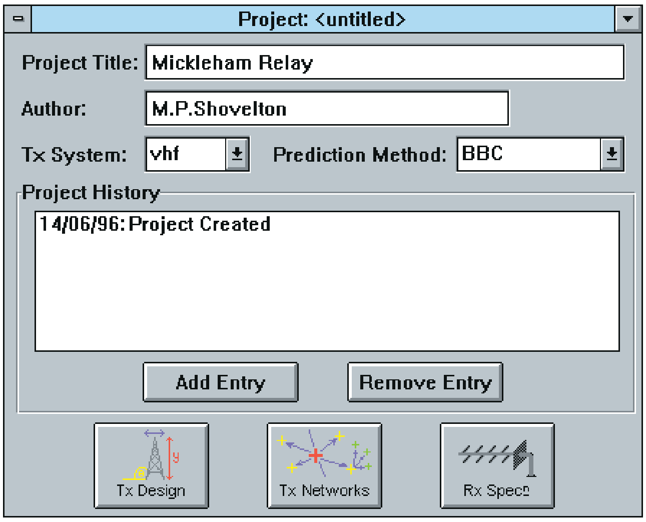
6.1.1 Specification

Appropriate buttons for selecting the required facility are accessible on the toolbar (as shown in Fig. 2). Fig. 5 *(overleaf)* shows an example of a main 'project' window; projects are used to specify the calculation run to be performed. This specification includes:

- *The transmitters to be included in the calculation.* This includes wanted and interfering transmitters. They can be specified using 'queries' which operate on the central database of known transmitters, or by describing them from first principles.
- *The area of interest.* This will be a rectangular

Table 2: Currently available transmission systems.

Ident.	Name	Analogue/Digital	Frequency Band	Modulation
uhf	I/PAL Television	Analogue	Band IV/V	AM VSB
vhf	FM Radio	Analogue	Band II	FM
dab	Eureka 147 DAB	Digital	Band III	COFDM
dtv	DVB-T Digital Television	Digital	Band IV/V	COFDM
mbl	PMR	Analogue	Band IV/V	AM or FM
djd	Fixed microwave links	Analogue	6 GHz	FM


Project: <untitled>

Project Title: Mickleham Relay

Author: M.P.Shovelton

Tx System: vhf

Prediction Method: BBC

Project History

14/06/96:Project Created

Fig. 5 - The Main Project Window.
(On creating or opening a project,
the Main Project Window will be presented.)

geographic area containing the ‘matrix’ of regularly-spaced receiving locations. The dimensions of the matrix are specified by the co-ordinates at its bottom-left and top-right corners. The spacing at the points can be anything from 50 metres upwards.

Other details which are essential to a project are also entered into the computer. These will include: the project title, to identify the project; the ‘author’, or creator of the project; the prediction method*, and the project history. All ‘specification’ entries are made on a **Windows/PC** system.

6.1.2 Calculation

The entered project specifications produce a file that is input to the calculation program, and the calculations are made, from all transmitters to all the receiving points, as if each transmitter were of 1 kW ERP and omni-directional. This work is done by a **Sun SPARC** mainframe computer.

The calculation program outputs a file containing for each:

- the 50%-, 95%- and 99%-of-time field strengths from the transmitter, still assuming a 1 kW omni-directional set-up;
- the angles of declination from the transmitter to the receiver for the three time cases;
- the angles of declination from the transmitter to the first obstruction for the three time cases;
- The types of propagation-loss calculations that have been used to calculate the field strengths for the three time cases — such as, free-space, line-of-sight, wedge, cylinder etc. (see Appendix 1 for information concerning the last two features).

and also:

- The details of every transmitter (from which the field strengths will be corrected during the analysis stage).

This calculated data, generated by the SPARC, is stored in the incoming interference *analysis* file.

6.1.3 Analysis

Incoming interference analysis is selected from the toolbar (Fig. 2) and is performed on a PC. Once the analysis file is loaded, the following tasks are performed:

- a map is created which links each receiving point to its corresponding matrix cell; this speeds up subsequent processing;
- field strengths are adjusted for the *actual* trans- mitter ERPs and radiation patterns;
- calculations are made for each transmitter, giving the preferred** or reference service — the overall results are composed from transmitters that are flagged for this purpose.
- For analogue services, the calculations produce:
  - i) the wanted field signal strengths for the preferred service at each receiving point;
  - ii) the protected field strengths*** from all the interferers at each receiving point;
- For digital services, the calculations produce:
  - i) the timing of each signal relative to the reference signal;
  - ii) the proportion of the power of each signal that is contributing;
  - iii) the proportion (as used later) of the power of each signal that is interfering.
- A *default matrix* is collated. The program typically produces: for analogue, the wanted field strength

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* Either ‘BBC Method’ or ‘REC-370’ (ITU Rec.370). See Appendix 1 for details of these.

** The method by which the preferred service is selected depends on the transmission system. For MFNs, it is usually the wanted trans- mitter which provides the highest field strength at each location. For SFNs (as used in the UK for DAB), the calculation is more complicated and involves the relative *timing*, as well as the field strengths, of the wanted signals.

*** In this case the protected field strengths are the interfering field strengths plus the protection ratio and receiving aerial protection.

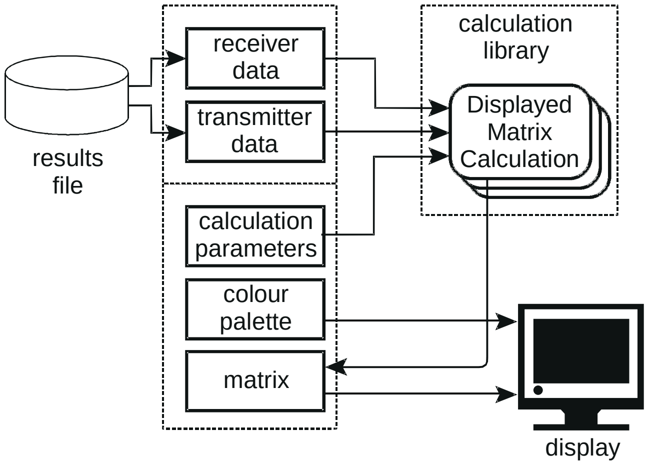


Fig. 6 - Calculation and display procedure of a displayed matrix.

for each point; for digital, the percentage of locations coverage for each point.

- A *terrain matrix* is collated. This contains the terrain height for each point; it is only calculated once and is used for a 3D projection display.

(It should be noted that PlanTx has facilities for the user to personalise the screen display. A colour palette, for example, is available for modifying the colours used to depict different values in the matrix cells. Zooming and panning the matrix display is another facility. These are not detailed in this Report because many facilities are still under development and their description would, in any case, be more appropriate for a user manual than a report.)

6.2 Displayed Matrix Calculation (DMC)

Once the analysis has been completed, there is a very large amount of information stored for each matrix cell. It can be seen, from the amount of data fed into the analysing process, that there are an almost unlimited number of ways to combine that data to produce a single value. Such a situation could easily lead to an overload of information and consequent confusion.

Therefore, a DMC is an algorithm for the combining of the data at **each** matrix point to produce a matrix value. The calculated value is shown in the matrix as a coloured square. There are two forms of DMC: *generic* and *transmission system specific*. The first, can be applied to all types of transmission systems; the second, to one type of transmission system only. Transmission system specific DMCs are stored in groups within calculation libraries. There can be any number of DMCs in one library and any number of libraries. Generic DMCs are all stored in the generic calculation library. Fig. 6 illustrates the matrix calculation and display procedure.

6.3 Access to the underlying data

In PlanTx, the layering of data ‘beneath’ the matrix gives access to more and more information as a descent through the layers is made. This provides a means for obtaining information in usable quantities, so that just one or more of the layers would be likely to give the required combinations of information. The coloured matrix display is the top layer, and there are several methods for accessing the underlying layers of data. Fig. 7 shows a sample screen display of a matrix.

6.3.1 Matrix interrogation — receiver data dialogue box

To interrogate a particular matrix cell, in order to obtain detailed data, the mouse cursor is placed over the required matrix cell and a point-and-click method of accessing the data is used to bring up a dialogue

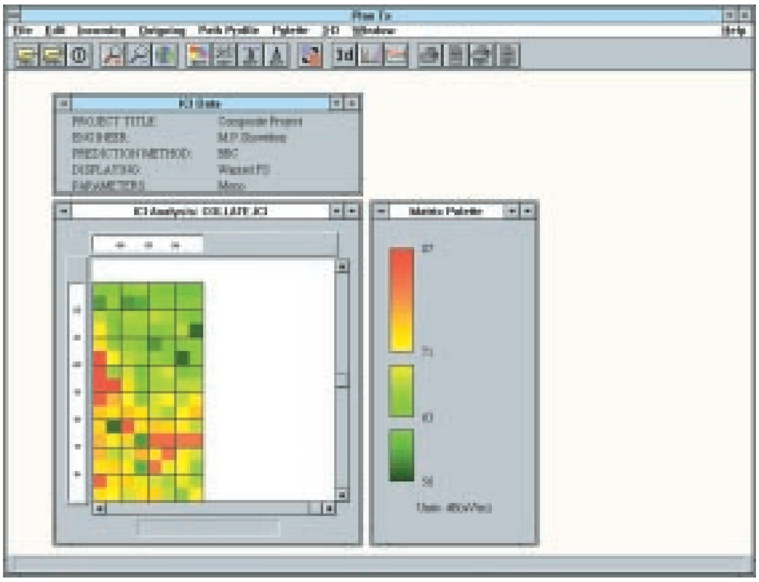
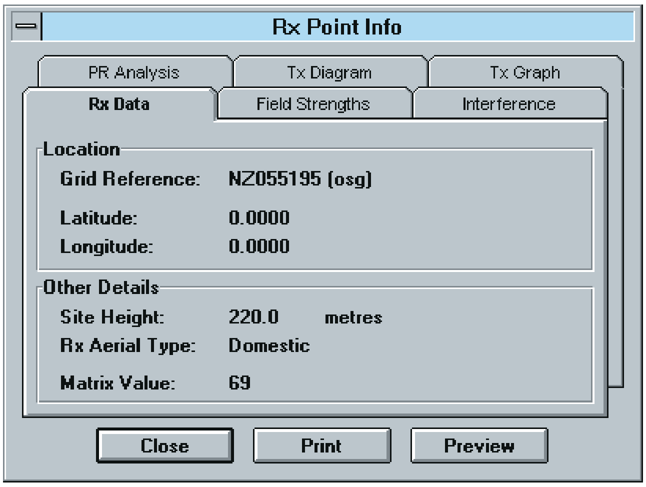


Fig. 7 - Incoming Interference Analysis.
(Showing the matrix points available for selection.)



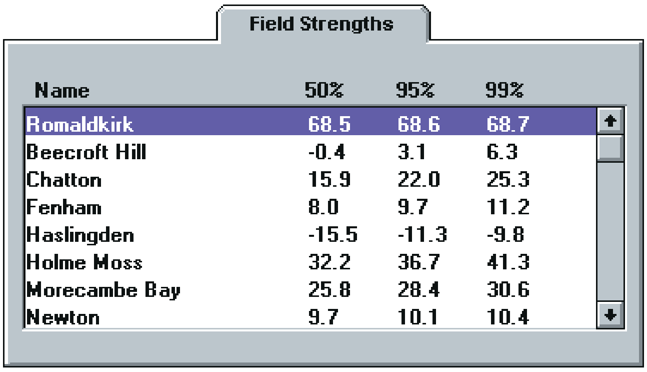
Location

Grid Reference:	NZ055195 (osg)
Latitude:	0.0000
Longitude:	0.0000

Other Details

Site Height:	220.0	metres
Rx Aerial Type:	Domestic	
Matrix Value:	69	

Fig. 8(a) - The Receiver and Transmitter Data Dialogue Box.



Name	50%	95%	99%
Romaldkirk	68.5	68.6	68.7
Beecroft Hill	-0.4	3.1	6.3
Chatton	15.9	22.0	25.3
Fenham	8.0	9.7	11.2
Haslingden	-15.5	-11.3	-9.8
Holme Moss	32.2	36.7	41.3
Morecambe Bay	25.8	28.4	30.6
Newton	9.7	10.1	10.4

Fig. 8(c) - The 'Field Strengths' Tab.

This tab contains ...

- *The 50%, 95% and 99% of time field strengths for each transmitter considered to be significant at the receiving point. The field strengths are correct for the actual characteristics of the transmitters. The transmitter highlighted in blue is the reference or preferred service transmitter.*

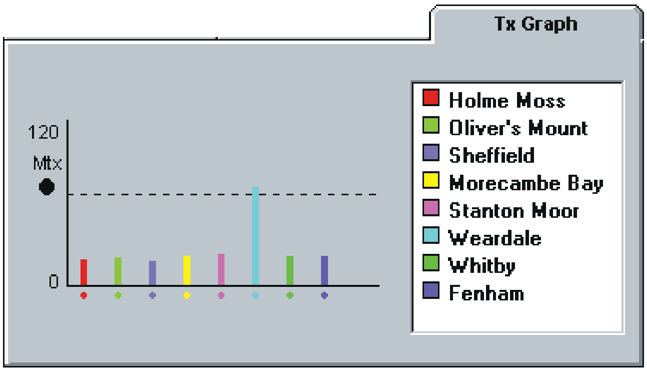
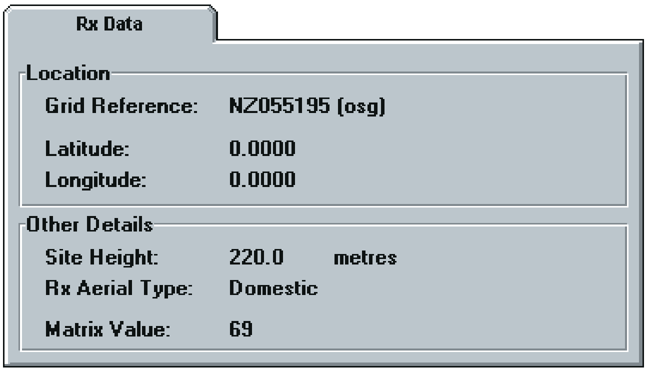


Fig. 8(e) - The 'Tx Graph' Tab.

This tab contains ...

- *A snapshot of the dynamic transmission graph (see also Figs. 9(a) and (b).*
- *This example is for an analogue multi-frequency network (MFN).*



Location

Grid Reference:	NZ055195 (osg)
Latitude:	0.0000
Longitude:	0.0000

Other Details

Site Height:	220.0	metres
Rx Aerial Type:	Domestic	
Matrix Value:	69	

Fig. 8(b) - The 'Rx Data' Tab.

This tab contains ...

- *Location details including the grid system and the grid reference, latitude and longitude.*
- *The site height in metres above sea level.*
- *The receiving antenna type.*
- *The single integer value calculated for this receiver point and currently displayed in the matrix.*

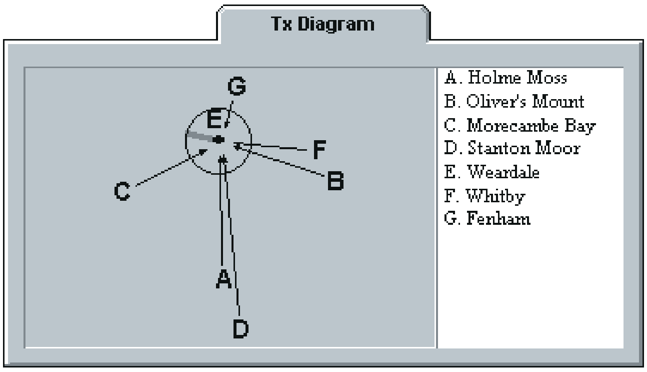
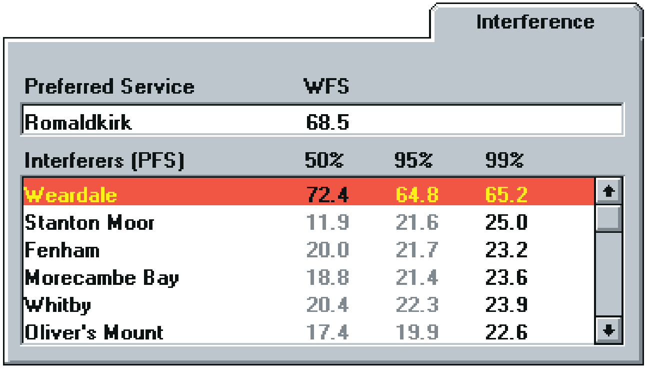


Fig. 8(d) - The 'Tx Diagram' Tab.

This tab contains ...

- *A diagram showing the physical locations of the seven most significant transmitters (at this receiving point) relative to the location of the receiving point.*
- *The receiving point is shown as the dot within the circle. With the exception of the preferred service, the transmitters are shown as the capital letters on the diagram. The bearing of the preferred service transmitter from the receiving point is indicated by the thick, dark grey line.*



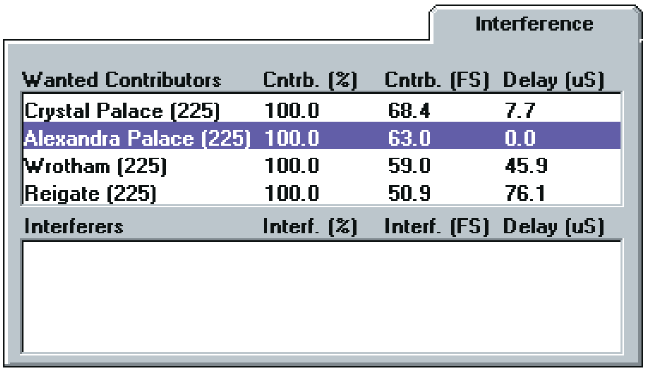
Preferred Service	WFS
Romaldkirk	68.5

Interferers (PFS)	50%	95%	99%
Weardale	72.4	64.8	65.2
Stanton Moor	11.9	21.6	25.0
Fenham	20.0	21.7	23.2
Morecambe Bay	18.8	21.4	23.6
Whitby	20.4	22.3	23.9
Oliver's Mount	17.4	19.9	22.6

Fig. 8(f) - The 'Interference' Tab (analogue version).

This tab contains ...

- *The wanted field strength from the preferred service transmitter.*
- *The 50%, 95% and 99% of time protected field strengths considering individually each of the interfering transmitters. The selected PFS is highlighted in black. Any transmitters for which the PFS exceeds the WFS is highlighted in red. Those transmitters excluded from the calculation have their names coloured grey.*



Wanted Contributors	Cntrb. (%)	Cntrb. (FS)	Delay (uS)
Crystal Palace (225)	100.0	68.4	7.7
Alexandra Palace (225)	100.0	63.0	0.0
Wrotham (225)	100.0	59.0	45.9
Reigate (225)	100.0	50.9	76.1

Interferers	Interf. (%)	Interf. (FS)	Delay (uS)

Fig. 8(g) - The 'Interference' Tab (digital version).

This tab contains ...

- *The proportion of each signal that is contributing to the coverage.*
- *The proportion of each signal that is producing interference.*
- *The time delay of each signal relative to the signal from the reference transmitter.*
- *The reference transmitter is highlighted in blue. Those transmitters excluded from the calculation have grey names.*

box; this will be the *receiver data dialogue box* for the receiving point represented by that selected matrix cell. As can be seen in Fig. 8(a), this box has three main areas of interest: the Tab Area, where other data menus can be selected; the Data Area, which gives the relevant data for that tabbed menu; the Print Preview and Print Buttons, where a print preview or a print command can be performed on a receiving point data sheet. Selecting a menu tab puts that particular menu to the front.

6.3.2 Matrix interrogation — transmitter data dialogue box

If more details are required about any transmitter, then the 'Field Strengths' or 'Interference' tabs may be selected from the 'Receiver and Transmitter Data' dialogue box (Fig. 8(a)). A **particular** transmitter can be selected from a transmitter list (e.g. like 'Romaldkirk', under the 'Field Strengths' tab, Fig. 8(c)); then a double click on the left hand mouse button brings up the *transmitter data dialogue box* for the selected transmitter. This contains four more dialogue menus, each selected by a point-and-click action on the required tab. All the relevant receiver and transmitter dialogues appear in the figures opposite.

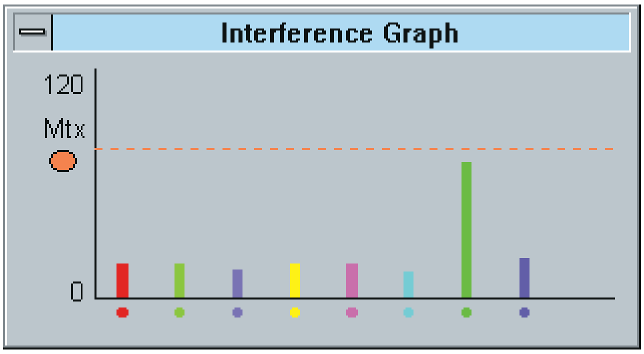
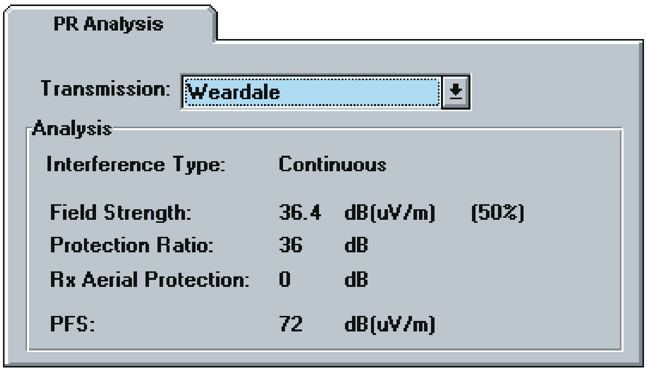


Fig. 9(a) - Dynamic Transmission Graphs for an ***Analogue m****ulti****f****requency* ***n****etwork.*



Transmission: Weardale

Interference Type: Continuous

Field Strength: 36.4 dB(uV/m) (50%)

Protection Ratio: 36 dB

Rx Aerial Protection: 0 dB

PFS: 72 dB(uV/m)

Fig. 8(h) - The 'PR Analysis' Tab (analogue only).

This tab contains ...

- *Detailed information concerning the calculation of the protected field strength considering each interfering transmission individually.*
- *The transmitter is selected using the 'combo-box' control.*
- *The PFS is split into its constituent parts. Namely, the interfering field strength, the protection ratio requirement and the receiving antenna discrimination ('Rx Aerial Protection').*

6.3.3 Matrix interrogation — dynamic transmission graph

Following a mouse-selection on the toolbar (Fig. 2), the user is able to roam around the matrix, using the mouse cursor, to see which transmissions are detectable at each individual receiving point. A bar graph (see Fig. 9(a)) shows the eight most significant transmissions, and dynamically updates the graph as the cursor moves around the cells. This figure indicates the protected field strengths, in an analogue or digital MFN, system for the eight worst interferers, against the wanted field strength from the preferred service transmitter. The bar graph is accompanied by a list box (not shown) that provides a colour-coded key, linking each coloured bar with its associated transmitter. Note, that as the cursor moves from receiving point to receiving point, the list of transmitters may change as their relevance changes. As a consequence of this, some transmitters' key colour codes may also change from one cell position to another.

Fig. 9(b) shows the field strengths from the eight transmitters which have the greatest effect on the coverage at the receiving point for a digital SFN. Also, the bars are split to show the contributing and interfering pro-

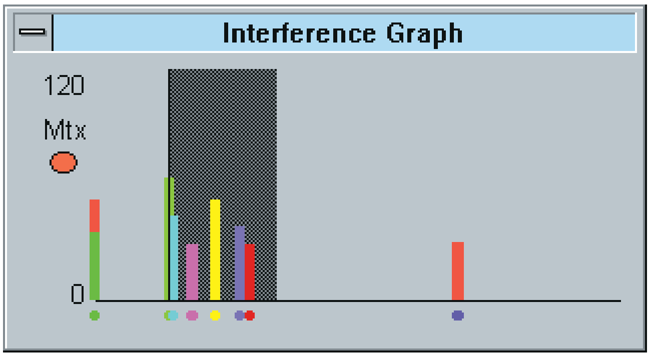


Fig. 9(b) - Dynamic Transmission Graphs for a ***Digital s****ingle* ***f****requency* ***n****etwork.*

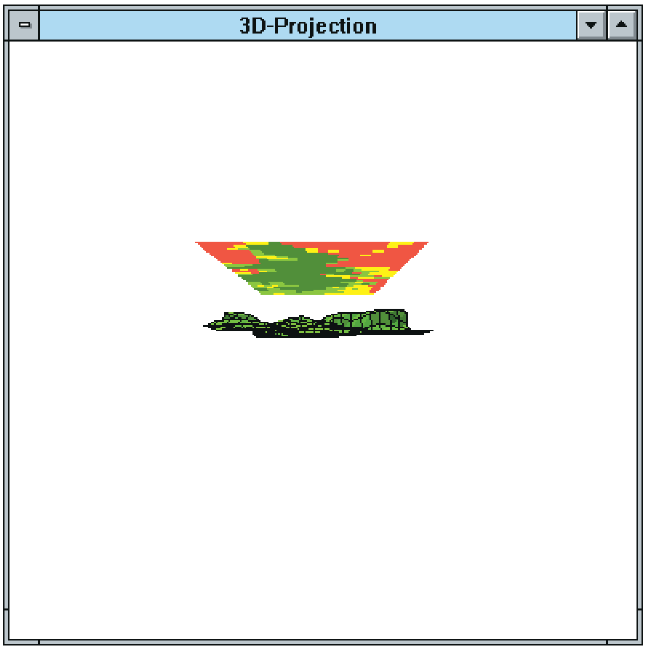


Fig. 10 - Showing the initial screen appearance of the 3D projection viewpoint.

portions of the signals; the upper part (red on the screen) is the interfering proportion — in the case of a signal which is 100% interfering, the whole bar appears red. For this reason, a coloured dot is placed beneath the bar to allow its identification. The x-axis shows the timing of the signals relative to that from the reference transmitter. The guard interval is shown in dark grey and is positioned so that it starts at the timing of the reference transmitter.

6.3.4 Matrix interrogation — 3D projection

PlanTx has the ability to generate a 3D projection that is based on terrain and matrix data. By another GUI toolbar selection, the projection can be viewed from almost any angle and configured to show a variety of combinations of terrain and matrix data. The display will project the area of the matrix displayed in the matrix window — if the matrix has been zoomed to enlarge it, only the visible area will be projected *not the entire matrix*.

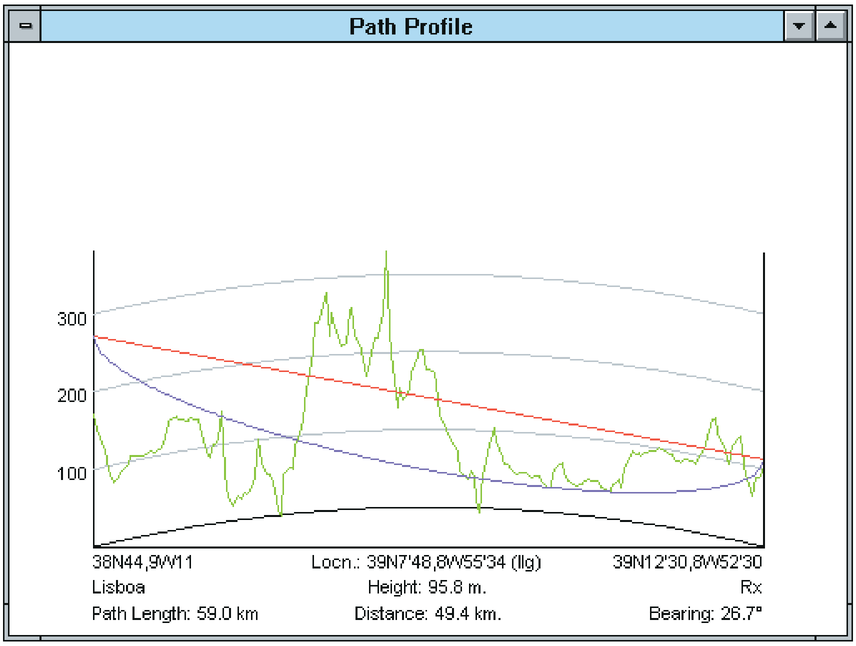
The projection can be set up to display projected terrain that is coloured according to field strength values. This allows easy visualisation of the effect terrain is having on the network coverage. Initially, the window will look something like Fig. 10. Also, the vertical spacing between the surfaces can be modified and a selection made of which surfaces are displayed and what data is used to generate them.

The 3D viewpoint dialogue screen allows the user to reposition the viewing point and modify the zoom and plane spacing. (See Section 6.4).

6.3.5 Matrix interrogation — terrain path profiles

Terrain path profiles form the basis of most current terrestrial, radio-frequency prediction methods. A terrain path profile is basically a two-dimensional graph of the terrain height along a straight-line path between two points on the Earth’s surface; usually between a transmitter and a receiving location, but PlanTx also allows a profile between any two points to be created (mouse-selecting from the Fig. 2 toolbar).

The path selection can be made by clicking on a cell and selecting terminal points manually, or by clicking and dragging the mouse cursor along the matrix between the desired points of interest; a terrain path profile is then generated. This display includes

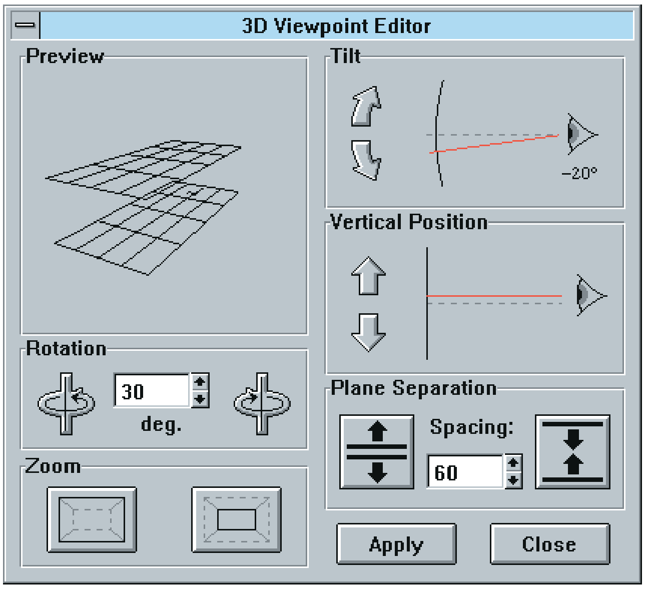


38N44,9W11
Lisboa
Path Length: 59.0 km

Locn.: 39N7'48,8W55'34 (llg)
Height: 95.8 m.
Distance: 49.4 km.

39N12'30,8W52'30
Rx
Bearing: 26.7°

Fig. 11 - Showing details of a Terrain Path Profile window.



Tilt: -20°

Rotation: 30 deg.

Spacing: 60

Fig. 12 - 3D-viewpoint dialogue screen for editing the 3D projection viewpoint.

modification of the terrain heights to account for the Earth's curvature and displays both the line-of-sight path and the First Fresnel Zone (see Fig. 11). Various colours are used to distinguish each feature and to make them easily recognisable — the line-of-sight path is in red, the First Fresnel Zone is in blue, the Earth's curvature is in black, and the terrain profile is in green.

6.4 Editing and configuring, printing and previewing

Editing facilities are selectable from the toolbar for each of the matrix-derived facilities described in the previous sections. A menu or dialogue system is made available, having intuitive designs and instructions which make the insertion of changes to a resulting display straightforward. Fig. 12, illustrates a typical editing facility (for 3D Projection), with a pictorial editor and a configuration dialogue box.

There is a comprehensive printing facility within PlanTx. The following are printable:

- Incoming Interference Matrix;
- 3D Projection;
- Receiving Point Data Sheet;
- Outgoing Interference Display;
- Terrain Path Profiles.

Print and Print Preview icons are available from the toolbar. Print Preview can display single pages, multiple pages (all pages which make up a main printout will be shown, except the cover) and Cover Page Mode (cover only). Fig. 13 shows (in the Print Preview Window) how the print-out of an entire matrix can be divided between eight landscape pages.

7. OUTGOING INTERFERENCE ANALYSIS

The Outgoing Interference Analysis (OGI) is the calculation and analysis of the interference radiated out to the service areas of existing transmitters as a result of a *new* transmitter being brought into use. This is a particularly important area, with respect to current efforts in setting up a terrestrial digital television network of transmitters in the United Kingdom within the present UHF band.

A list of geographical locations ('test points') is required for Outgoing Interference Analysis (see also, Section 6 for details). These are pre-defined and lie at key points within the service area of every planned transmitter. They are used during the 'calculation' process, as given below. As before, both the Windows-based PC and SPARC-UNIX computer platforms are used.

7.1 Basic procedure

This follows a similar line to that adopted for the Incoming Interference Analysis case; namely, using a three-stage method for producing a final analysed result: **Specification**, **Calculation** and **Analysis**.

7.1.1 Specification

A new transmitter may either be specified fully by the user (using the transmitter design tool) or retrieved from the central transmitter database. The user must also specify the existing network transmitters with

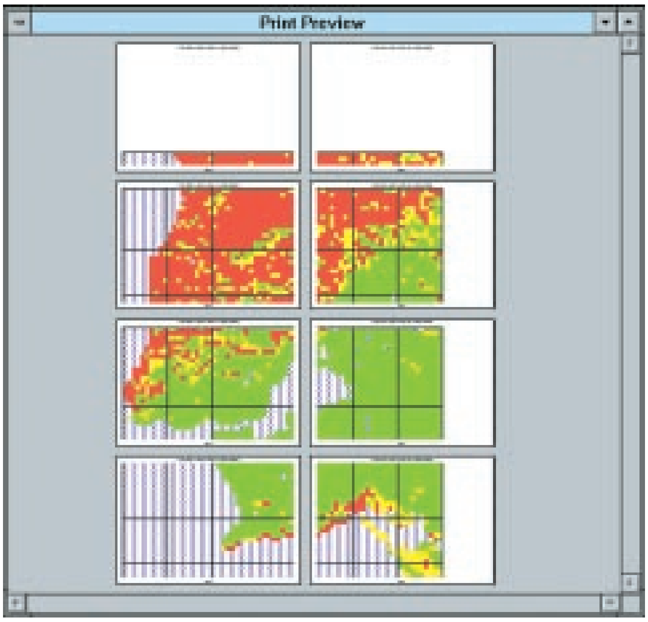


Fig. 13 - Illustrating the kind of extensive use that can be made of the printing facility.
(Eight adjoining landscaped pages.)

which the new transmitter is likely to interfere (e.g. The co-channel or adjacent channel transmitters). The resulting file will then be used for the calculation of field strengths (Section 7.1.2 below).

7.1.2 Calculation

Calculations are made of the field strengths of signals from the *new* transmitter at all of the test points, along with the field strengths from the network of *existing* transmitters to their respective groups of test points. As with the Incoming Interference Analysis calculations, the **SPARC computer system** is used for this; again, with all transmitters initially considered to be of 1 kW ERP and omni-directional — to be modified later to realise the *actual* radiation pattern and ERP of each transmitter.

7.1.3 Analysis

This also follows a very similar routine to that given in Section 6.1.3, for the Incoming Interference Analysis, the appropriate ('calculation') file being selected from a toolbar-obtained menu. The file details are read and then the field strengths are adjusted for the *actual* ERPs. and radiation patterns. First, wanted field strengths are calculated for the network of transmitters at each appropriate test point; then, the protected field strengths taking account of interference from the new transmitter are calculated at all the test points. This work is completed on a **PC**.

7.2 OGI displays

On completion of the analysis, an OGI analysis window is created and displayed. The display operates in two modes: **Star Chart**, and **Scatter Graph**. The Star Chart has two display levels, Global level and Transmitter level, as shown in Figs. 14(a) and (b), and discussed in Sections 7.2.1 and 7.2.2 following.

7.2.1 Star chart

Global Level — This shows the locations of the existing transmitters (both national and nearby international) whose service areas could be affected by the new transmission. These transmitters are generally selected on a frequency basis. The transmitters are colour-coded according to whether their service areas are actually affected (red) or not (blue); see Fig. 14(a) opposite.

A transmitter is said to be affected if one or more of its test-points acquires a higher Protected Field Strength (PFS) on account of the new interference than its *wanted* Field Strength (FS). NOTE: *PFS = FS of wanted transmissions + Protection Ratio + receiving antenna protection*. The *Protection Ratio* is that maximum value of interfering signal that is allowable, compared to the wanted signal, for good local reception. The *receiving antenna* has a discrimination between signals at different angles and is *assumed* to be of correct antenna band [or group] and directed towards the intended transmitter for that service area. Effective receiving antenna usage is an area of uncertainty, there being no way of examining each and every antenna in use. Many are likely to be unsuitable, with possible dire consequences for future television reception in those households!

Transmitter Level — This display (Fig. 14(b)) shows the locations of a selected single transmitter and its test points. It allows the detail of *one particular* transmitter in a network to be viewed and displayed which areas of its service are affected. The test points are colour coded according to the margin (Margin = Wanted Field Strength [WFS] – Protected Field Strength [PFS]). Fig. 14(c) shows the symbols used and the keys to the colour codings.

7.2.2 Scatter graph

The Scatter Graph display (see Fig. 15 *(page 14)*) shows the interference caused from the point of view of the new transmitter. The display contains the test-points of all the network transmitters, and are colour coded according to the margin (see Fig. 14(c)). The test points are positioned using radial co-ordinates around the new transmitter (which lies at the centre of the display), such, that:

- The radius of the co-ordinate is dependent on the margin at the test-point (the more interference received, the closer the test-point is to the centre of the graph).

- The bearing of the co-ordinate is dependent on the direction of the receiving point from the new transmitter.

The inner concentric circle in Fig. 15 indicates a margin of 0. Therefore, test-points within this circle are receiving interference from the new transmitter. The outer circle indicates a margin of +12. Test-points with a margin of greater than or equal to +12 are positioned on this circle.

7.2.3 Geographical Information System (GIS) Interaction

The display of a coloured matrix or of a star chart of transmitters in isolation is not particularly useful. To allow easy visualisation of the information, the positions of matrix cells and transmitters must be displayed relative to geographical information in the form of suitable maps, in a manner that will clearly relate the areas of coverage to the population centres or major roads. PlanTx implements two methods for relating calculated data to geographical information:

1. The display of results can be printed to any scale onto a transparent film. This can then be overlaid

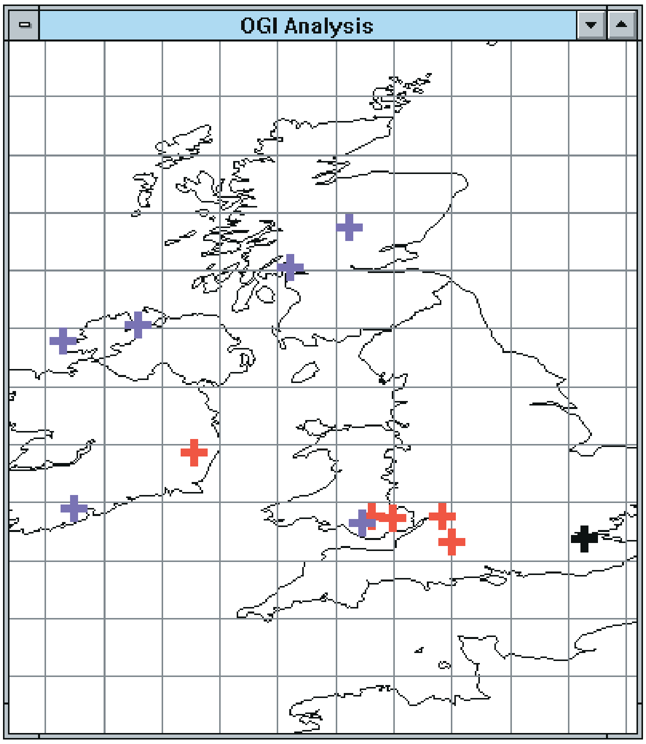


Fig. 14(a) - The Global Level screen, showing the locations of existing transmitters that could be affected by the new transmission.

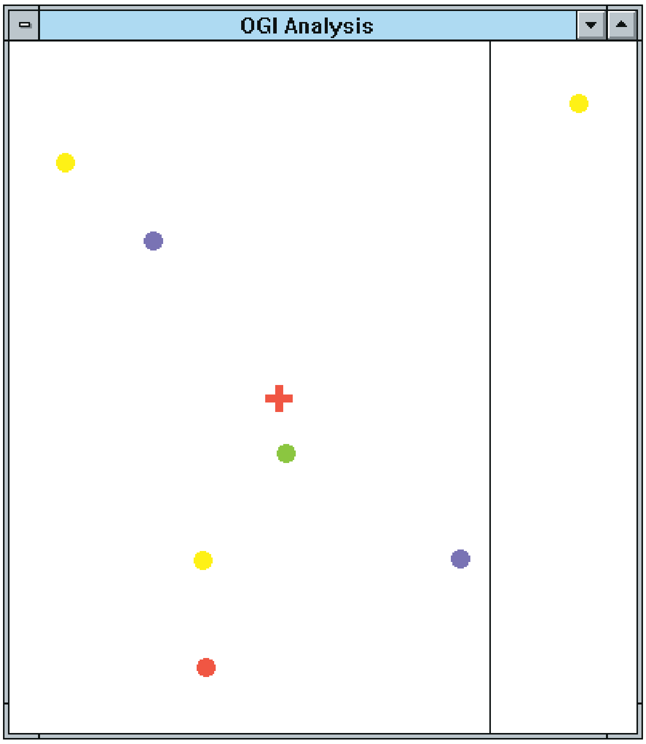


Fig. 14(b) - The Transmitter Level screen, showing the locations of a single network transmitter and its test points.

onto a suitable map. This is satisfactory for producing final hard-copy output but is obviously inadequate for interactive work.

2. PlanTx data can be exported in a form that is readable by the popular ‘WINGS’ GIS.

8. CONCLUSIONS

This Report has endeavoured to give a brief description of the main areas of importance within the PlanTx software suite. It is one of the most advanced systems available and has many unique features. One of its greatest strengths is the use it makes of a prediction method developed by BBC Research Department (as it was then called) some 20 years ago. The basics of this are outlined in Appendix 1.

The Report has shown that, by using the Windows-based user interface for all the work (including that where a Unix mainframe system is used to carry out the computing), a well-known approach to present-day computing has been incorporated into this prediction system. Comparatively powerful, readily-available and cost-effective personal computers, which are constantly being uprated, are a firmly established part of the PlanTx system; no esoteric hardware is therefore required. Having stated this, it should be understood that only trained and very knowledgable engineers could possibly make effective use of the system. (Having a word processor, for example, does not make the user an expert author!)

The ability to extensively edit parts of the programs, in order to customise them to meet the user’s personal preferences or the planning department’s requirements, is an important feature of PlanTx that aids interpretation of results. These results can then be printed in a wide variety of formats to suit most needs; for example, the production of printouts that ‘make sense’ to

Transmitters

- ✚ Wanted / new transmitter
- ✚ Transmitter unaffected by interference from new tx
- ✚ Transmitter affected by interference from new tx

Receiver points

- 🟦 Margin ≥ 6 dB
- 🟩 0 dB ≤ margin < 6 dB
- 🟨 -6 dB < margin < 0 dB
- 🟥 Margin ≤ -6 dB

The symbols used in the displays are:

- ✚ Transmitter
- ● Domestic receiver point
- ▲ Re-broadcast Link (RBL)

Fig. 14(c) - The Colour Palettes and Symbols used in the ‘Outgoing Interference’ displays.

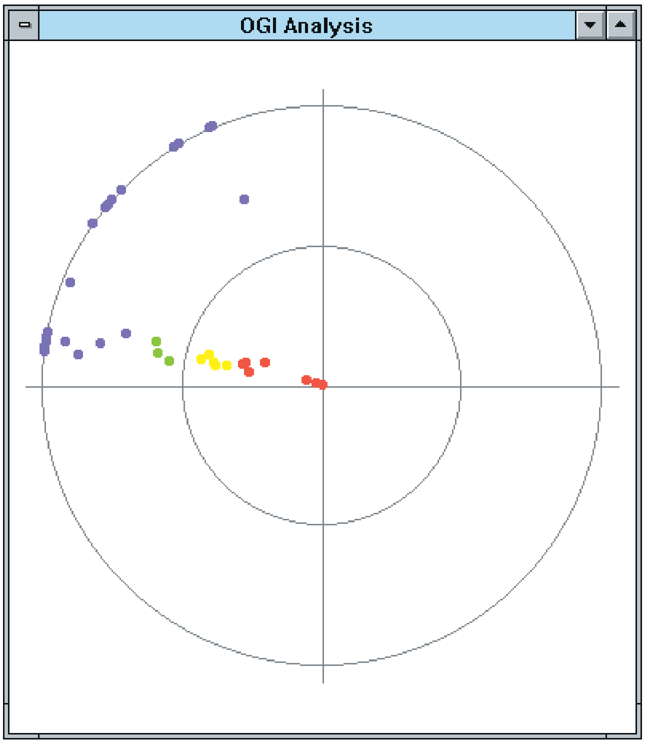


Fig. 15: Scatter Graph display.

lay personnel charged with organising broadcast programme outputs. These features have been dealt with in this Report.

The flexibility of the PlanTx library systems ensures that virtually all likely future developments, or the requirements of other countries not yet accounted for in the system, can be integrated into the software applications. In addition to this, further improvements can be incorporated into PlanTx without having to nullify earlier work within the package; consequently, continuing improvements can be made to take full advantage of any increased PC hardware performances that will inevitably be forthcoming.

The PlanTx planning tool is truly 'universal'; it will work on a wide range of frequency spectrum and account for many types of transmission systems. Upgrading work continues, in order to further broaden the scope of this innovative piece of equipment. A case study of one piece of site work is contained in Appendix 2.

9. REFERENCES

1. CAUSEBROOK, J.H., DAVIS, B., EATON, J.L., KING, R.W., KNIGHT,P. *and* LEE, R.W., 1982. Computer prediction of field strength: A manual on methods developed by the BBC for the LF, MF, VHF and UHF bands. BBC Research Department.

2. CCIR Recommendation 370-5, 1990. VHF and UHF propagation curves for the frequency range 30 MHz to 1000 MHz, Documents of the XVIIIth Plenary Assembly, Dusseldorf, **V**(5D).

3. CAUSEBROOK, J.H., DAVIS, B *and* SANDELL, R.S., 1969. The prediction of co-channel interference to television broadcasting services in the frequency range 470 to 960 MHz. BBC Research Department Report RD 1969/33.

4. LEE, R.W., CAUSEBROOK, J.H. *and* SANDELL, R.S., 1970. An investigation into the prediction of field strength: 'The Guildford experiment'. BBC Research Department Report RD 1970/26.

5. CAUSEBROOK, J.H. *and* DAVIES, B., 1971. Tropospheric radio wave propagation over irregular terrain: The computation of field strength for UHF broadcasting. BBC Research Department Report RD 1971/43.

6. CAUSEBROOK, J.H. *and* TAIT, B., 1978. Computer programs for v.h.f. interference prediction using a terrain data bank. BBC Research Department Report RD 1978/13.

7. SANDELL, R.S., DAVIES, B. *and* CAUSEBROOK, J.H., 1967. Calculation of the field strength required for a television service in the presence of co-channel interfering signals: Part 1: The assessment of a single interfering source. BBC Research Department Report RD 1967/52.

APPENDIX 1

This appendix briefly describes the different prediction methods available to the user of ‘PlanTx’. There is no attempt to explain these methods in detail, but they are listed in order to show the distinct differences between them.

The BBC Method

Identifier: BBC

Comments: This is the method known as the ‘BBC Method’. It was developed at BBC Research Department (now BBC R&D) over 20 years ago. The method is based on the modelling of a terrain path profile by approximating it to basic mathematical shapes (knife edges, wedges or cylinders) and calculating the diffraction of the signal over these shapes. In general, the method is much more accurate than Rec. 370.

This version has been ‘fine tuned’ to make it particularly suitable for the UK. Therefore, it may not be so accurate in countries with differing terrain and urban distribution. See Ref. 1 for further details.

ITU-R Recommendation 370

Identifier: Rec. 370

Comments: This method is based on a set of curves which have been defined for differing effective antenna heights and path types (land, cold sea, warm sea, hot sea). The effective antenna height is calculated as the height of the antenna above the mean terrain height. This method, although not very accurate for coverage predictions, is used extensively for international co-ordination as it is the only currently agreed method. See Ref. 2 for more information.

APPENDIX 2

Digital television planning — A case study

In the UK, the BBC is collaborating with other organisations* to build the UK frequency plan for digital terrestrial television. The UHF Band IV and V spectrum is already heavily occupied by the UK's extensive analogue television network. Therefore, there is no new spectrum available for digital television and it is necessary to re-use the channels currently used for analogue television. This 'interleaved planning' requires sophisticated planning methods and tools. It is essential that existing analogue services are not compromised by the introduction of new digital services.

PlanTx is being used to ascertain the effect that a new digital service will have on existing analogue transmitters' service areas. This is a good example of PlanTx's ability to model heterogeneous interference scenarios. A calculation is performed using the following method:

1. The coverage of the analogue transmitter is calculated using the BBC's terrain-based propagation methods.

2. The effects of existing analogue interferers are calculated to determine the current service area of the analogue transmitter.

3. The effect of adding one or more digital interferers is assessed using the protection ratios appropriate for that service. This results in a plot of the service area limited by both analogue and digital interference.

4. A plot of the difference between stages 2 and 3 is produced. This shows the areas which have lost coverage on account of the digital signal. An example of this type of plot is illustrated in Fig. A2.1 below.

The same approach is also used to determine (more precisely than can be found using the internationally-agreed Recommendation 370) the restrictions to digital services which would be required to protect analogue services in other countries. These detailed studies are fundamental to efficient use of the broadcast channels and the introduction of digital television in the UK.

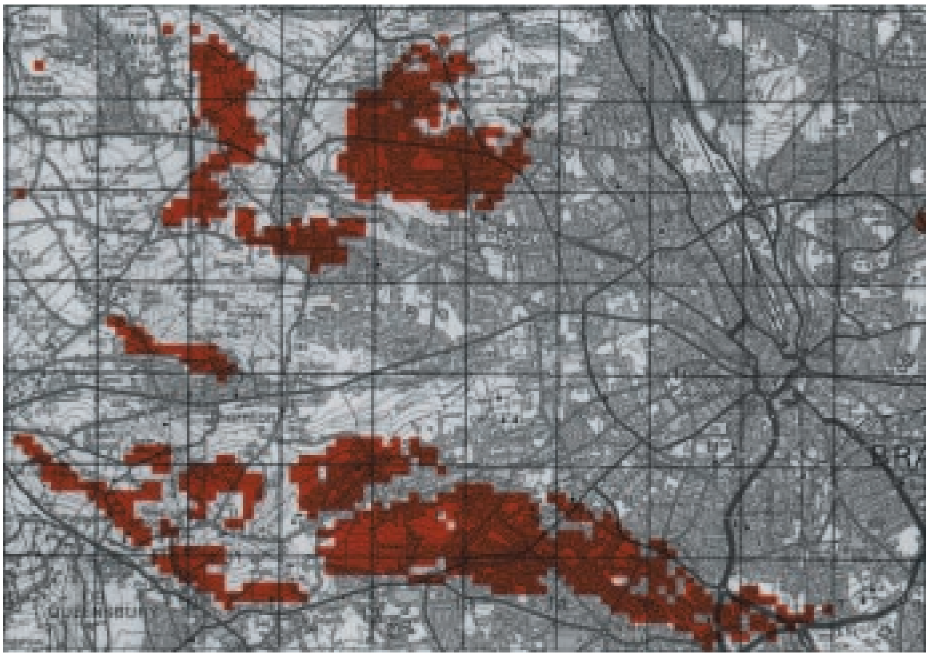


Fig. A2.1 - Loss of Idle's analogue television service area due to interference from a proposed digital television service transmitted from Bilsdale.

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* The Independent Television Commission (ITC) and National Telecommunications Limited (NTL).

Published by BBC RESEARCH & DEVELOPMENT DEPARTMENT, Kingswood Warren, Tadworth, Surrey, KT20 6NP